

Workshop on Containerless Experimentation in Microgravity

Thermophysical Property Measurements in Electromagnetic Levitators

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Proper measurements of thermophysical properties of hot levitated liquid drops require the following:

1. Accurate Temperature Measurement
 - a. Brightness measurement
 - b. Emissivity measurement
2. Precise Drop Shape Measurements with Submillisecond Time Resolution
 - a. Density determination
 - b. Rotational and vibrational shape information
3. Precise Control of Drop Shape
 - a. High symmetry variable gap levitators
4. Accurate Energy Transfer Measurements
 - a. Direct measurements of energy transfer rates for defined gas flows over samples with Quantitative measurements of energy transfer rates for defined gas flows over samples with known shapes
5. Precise Measurements of Repetitive Sample Motions
 - a. Rapid repetitive shape measurements
 - b. Frequency measurements with reflected laser light
 - c. Measurements in the levitator and as a freely falling drop

Recent advances in coil design and control of sample rotation in an electromagnetic levitator will be discussed with respect to the above requirements

The Primary Electromagnetic Levitation Problem has been Uncontrolled Sample Motion

Uncontrolled sample motion is thought to result from a number of causes either singly or in combination as follow.

Flux Inhomogeneity

Inhomogeneity of the coil magnetic flux field results from lack of physical symmetry of the coil. Inhomogenous fields can result in large sample oscillations during melting and nonsymmetric drop shapes.

Nonuniform Heating

Non-uniform sample heating can result in a net circular mass flow within the sample. Non-uniform heating will result from nonuniform flux fields and non-spherical sample shapes such as that caused by the earth's gravitational field.

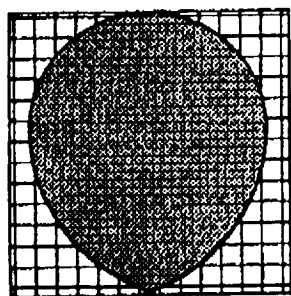
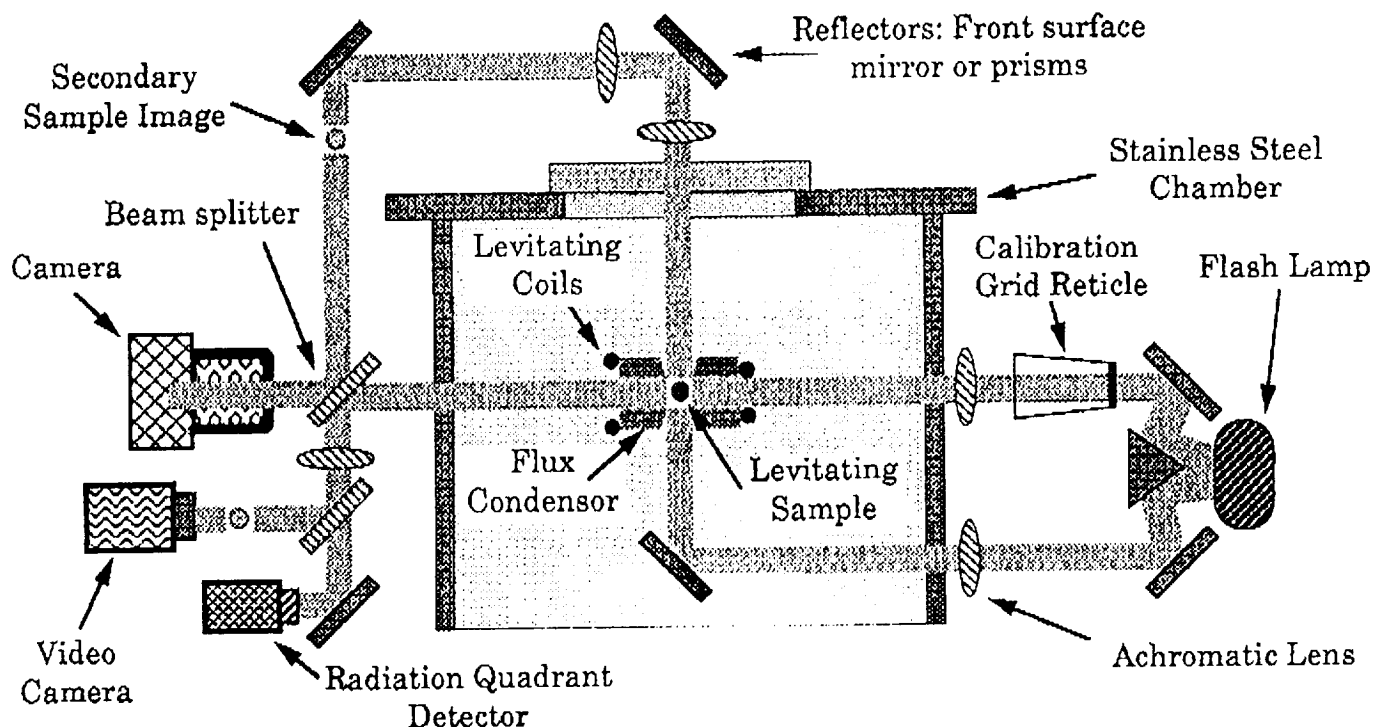
Coil Vibration

The importance of physical vibration of the coil is unknown but can be quite important since levitation coils are usually suspended on long lever arms which can cause the coil to be sensitive to vibrations present in the chamber.

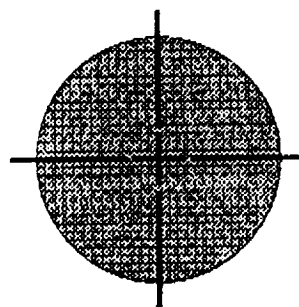
RF Source Modulation

Low frequency modulation of the RF power supply, sixty cycle and overtone modulation of the high power RF supplies is often present due to incomplete rectification of the line sixty cycle power. Since levitation forces are directly dependent on the RF power its modulation will directly couple energy into the oscillations of the sample.

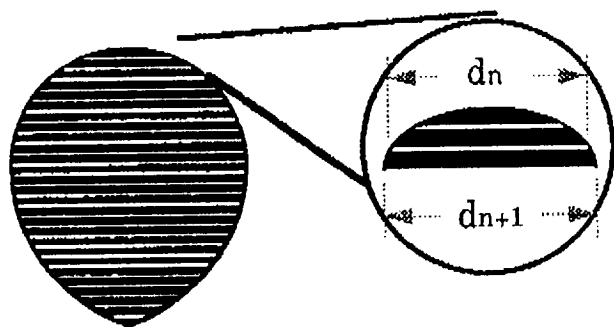
Liquid Drop Density Measurements In An Electromagnetic Levitator



Profile of levitating sample as seen in Camera with Calibration Grid



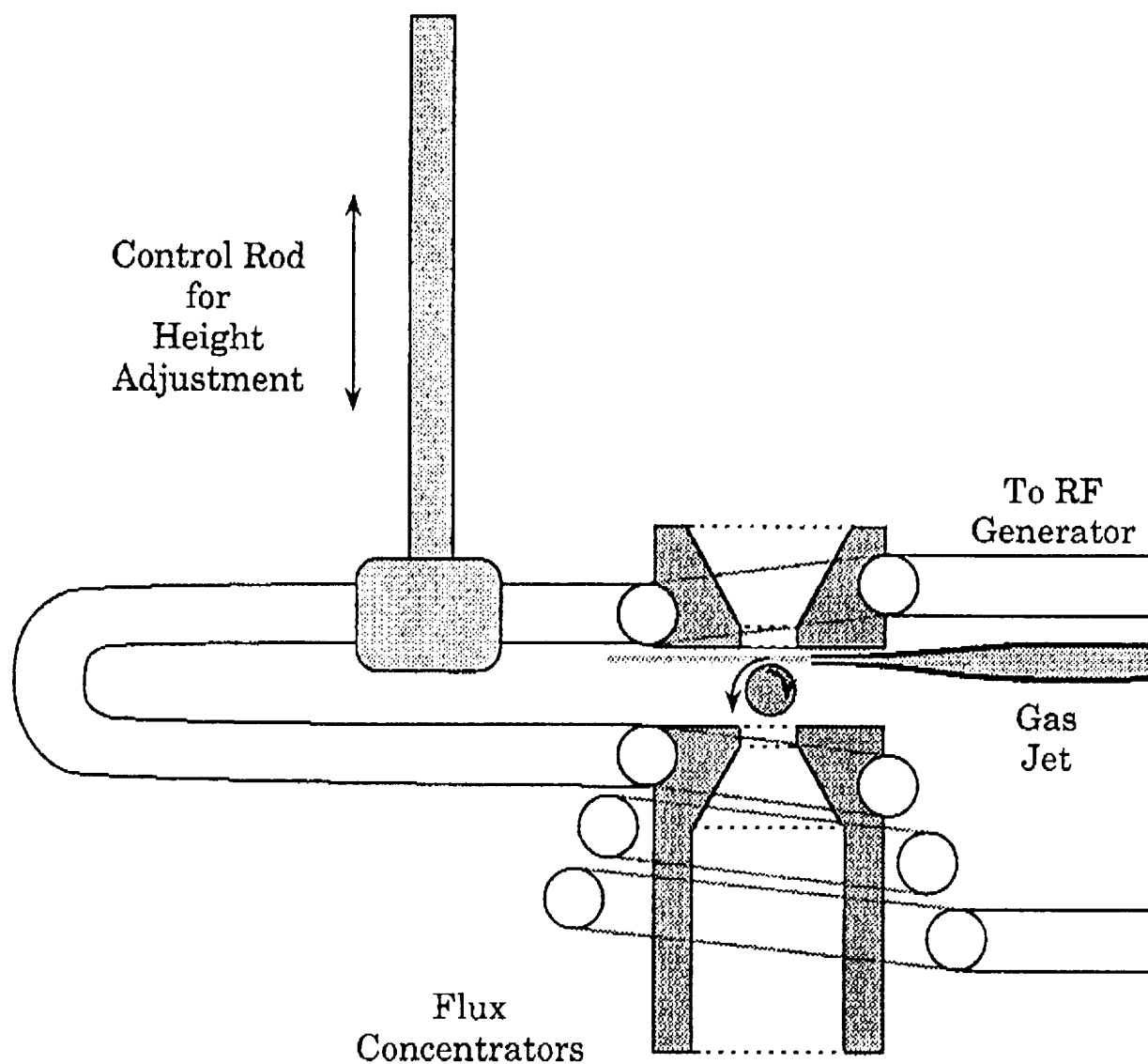
Top View of levitating sample as seen in Camera & RQD



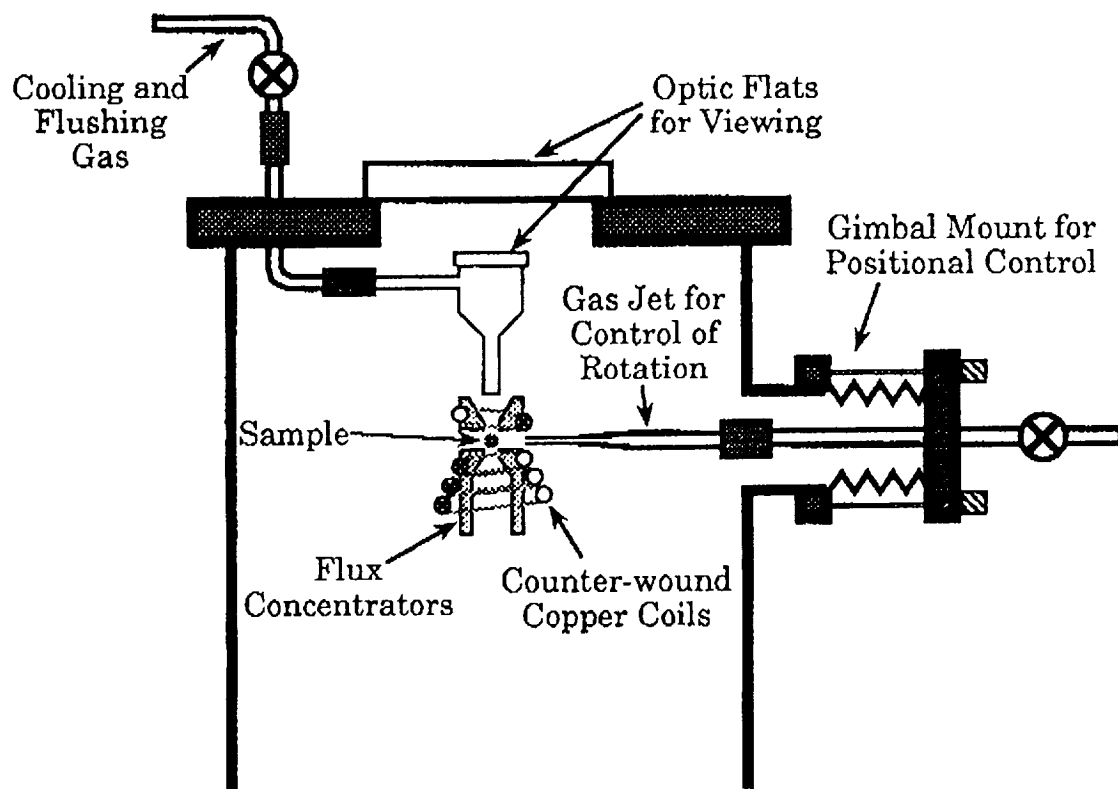
Scanned sample image equipartitioned for volume calculation

$$\begin{aligned} \text{Total Volume} &= \sum \text{all slices} \\ \text{Volume of each slice} &\approx \pi \left(\frac{d_n + d_{n+1}}{4} \right)^2 (\Delta h) \end{aligned}$$

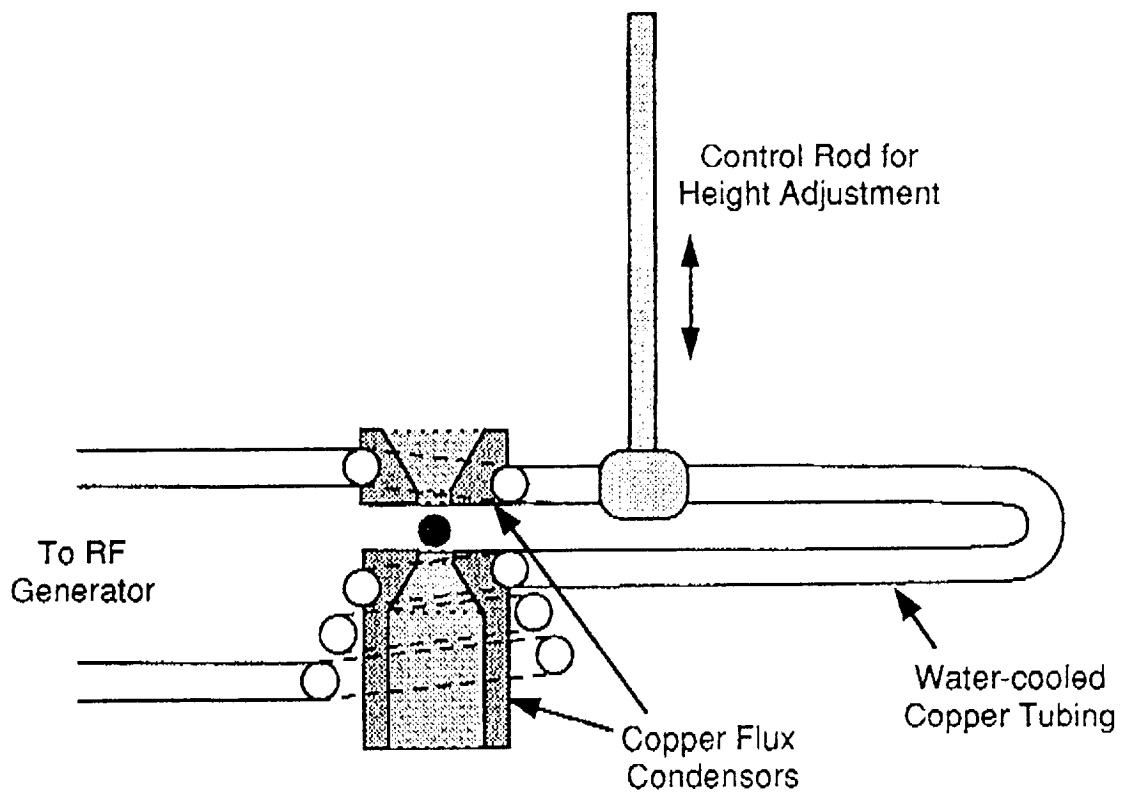
Modifications for Drop Shape and Spin Control (Expanded View)



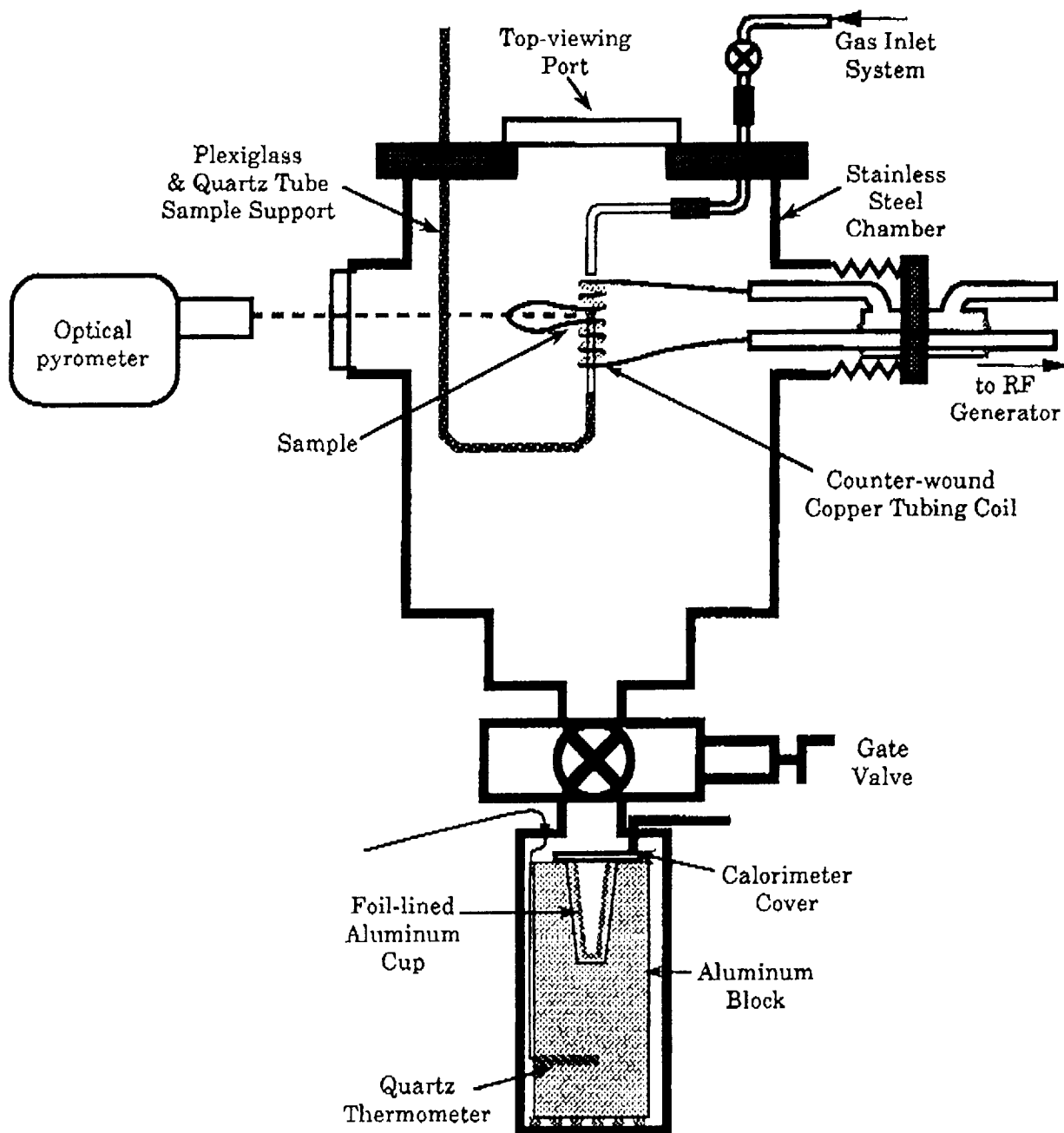
Modifications for Drop Shape and Spin Control



Flux Concentration Levitator with Variable Gap



Calorimetry Set-up



Suggestion For Improved Coil Symmetry, Coupling to the Sample & Sample Control

Use of Flux Concentration

Magnetic flux homogeneity can be achieved with a technique of flux concentration. This involves the use of split copper plates or tubes with center holes. Each plate is attached to and cooled by a turn of the solenoid coil nearest the sample. The RF current flows primarily around the inner surface of the center hole. This serves to concentrate the flux and also to give a uniform radial distribution. When plates are attached to both the upper and lower coil, the flux radial uniformity is expected to be much improved over those present in existing coils.

Variable Gap Coils

Efficient sample heating will ultimately permit smaller RF generators to be used. A factor which critically affects sample heating; is the distance between the sample surface and the coil. A variable gap between the upper and lower coils of a levitation coil allows for optimization of sample-coil distances.

Sample Rotational Control

Rotational control of the sample can be achieved with gas jets. A moveable point source of high velocity gas which is located to either side of the sample induces a counter-rotation of bath gas around the sample. This allows one to either decrease or increase sample rotation rate.